Observations on the feeding behaviour of Strongylosoma stigmatosum (Eichwald) (Diplopoda: Polydesmoidea)

By

M. POBOZSNY*

Abstract. Adult specimens of the millipede *Strongylosoma stigmatosum* (EICHWALD) were fed under experimental conditions on the litter of four broad-leaved (*Carpinus betulus, Quercus petraea, Q. cerris, Fagus silvatica*) and four coniferous tree species (*Pinus nigra, P. sylvestris, P. strobus, Picea abies*). On the basis of our findings it can be stated, that: *1.* The broad-leaved litter consumption varied between 2.8 and 17.1 mg/g fresh mass/day, depending on the age (actual level of the previous microbiological transformation) of the litter and the physical parameters of the environment. *2.* Freshly fallen leaves, which had not been attacked by microorganisms, were not consumed at all. *3.* Hornbeam leaves were preferred the most by these animals. *4.* The average *Pinus nigra* litter matter consumed varied between 1.4 — 12.6 mg/g/day. *5.* The needle litter of *Picea abies* was preferred the most and that of Pinus strobus the least. *6.* The calculated assimilation efficiency values (29.6 — 42.2 % on leaf litter and 23.6 — 47.6 % on needle litter) were high.

Saprophagous arthropods can play a decisive role in litter communities by their intense physical destruction of organic remainders, in the cycling of chemical elements of forest soil ecosystems (SZABÓ & al., 1990). The diplopod species *Strongylosoma stigmatosum* (EICHWALD) frequently colonizes the litter layers in broad-leaved forests developing on limestone base rock in the middle mountains of Central Europe. This millipede of wide ranging ecological valency occurs also in a number of Hungarian forest habitats, especially in the forest stands of the Transdanubian Mountains (ILOSVAY, 1982, 1983; LOKSA, 1961a, 1961b, 1971, 1977, 1991).

In the literature there are a lot of data on the biology and ecology of this important species (see SEIFERT's revue, 1932). Unfortunately, however, little is known on its feeding behaviour. The aim of our work presented below was to study the dynamics of food consumption, the faecal pellet production and the order of food preference of this millipede species under controlled environmental conditions.

* *Dr. Mária Pobozsny*, ELTE Állatrendszertani és Ökológiai Tanszék, MTA Talajzoológiai Kutatócsoport (Department of Systematic Zoology and Ecology of the Eötvös Loránd University, Section of Soil Zoology of the Hungarian Academy of Sciences), 1088 Budapest, Puskin u. 3, Hungary.

Materials and methods

Food preference experiments were carried out between late October 1990 and May 1991, using litter leaves of different broad-leaved plant species (*Quercus petraea, Q. cerris, Carpinus betulus* and *Fagus silvatica*) as food materials (collected in the time of litter fall in October and thereafter in every second month till April), at changing (between 3° and 15° C) outer temperature values in our Department (Budapest). The feeding experiments using only the needle litter of *Pinus nigra* as the animals exposed food matter were carried out in a cave laboratory (Aggtelek, NE Hungary) with a constant temperature (10° C). Furthermore a series of food preference experiments with the needle litter of four different conifers (*Pinus nigra, P. sylvestris, P. strobus* and *Picea abies*) were performed in a refrigerator at a constant temperature value of 10° C (Pobozsny, 1992). The weighed food matter of constant humidity (water loss was compensated from time to time by spraying) and a given number of the weighed millipede specimens were placed together into the experimental pots. The high relative air-humidity (98—100 per cent) in the cave guaranteed the constant water content of the exposed litter matter. In the cave laboratory earthenware pots of 10 cm diameter and 12 cm height covered with nylon mesh, in all other cases covered plastic boxes of 25 cm x 20 cm x 15 cm.

Specimens of *S. stigmatosum* were collected for these experiments from the litter layer of a hornbeam-oak (Querceto-Carpinetum) forest stand in the Vértes Mountains in Hungary. Till the beginning of the experiments the animals were fed (at 10° C) with mixed leaf litter collected at the original sampling site.

At the end of the feeding periods the live mass of animals, the air dried and absolute dry mass (constant mass at 105° C temperature) of the remained litter matter and the produced faecal pellets were determined. All examinations were made on 5 or 10 samples and the same numbers of control experiments (without animals).

The food consumption was calculated by using the Reiman formula (Zicsi & Pobozsny, 1977). Usual statistical methods were applied in the analysis of the obtained data.

Results and discussion

Food consumption and egestion

Data on the leaf litter consumption and those on the cast production of *S. stigmatosum* can be seen in Table 1. The total food consumption was relatively high (17.1 mg/g fresh mass/day) in October, but considerably decreased till December, and slightly increased from February. During the study period the level of leaf litter consumption was significantly higher in October than in other months (see Table 1/a.), but during the subsequent months did not differ significantly. These changes in the animals' feeding activities correlated with the low air temperature values.

Table 1. Litter consumption and faecal pellet production by S. stigmatosum adult specimens (SD)

Month of leaf litter sampling	Consumption *Quercus petraea*	*Quercus cerris* mg/g/ day	*Carpinus betulus*	*Fagus silvatica*	Total	Egestion mg/g/day
October	9.6 (1.2)	6.2 (1.4)	0	1.3 (0.8)	17.1 (0.8)	10.1 (3.7)
December	0.7 (0.06)	0.5 (0.6)	1.2 (0.1)	0.4 (0.6)	2.8 (0.7)	1.0 (0.6)
February	0.4 (0.04)	-	3.1 (1.9)	0.5 (0.2)	4.0 (1.8)	2.7 (0.8)
April	0.5 (0.3)	-	3.8 (1.7)	1.6 (0.05)	5.9 (2.0)	3.8 (1.0)

Table 1/a. A comparison of total leaf litter consumptions measured in different months (t-test)

	October	December	February	April
October	-	xxxx	xxxx	xxx
December		-	0	0
February			-	0
April				-

Significant differences: xxxx $P< 0.001$
xxx $P< 0.002$
0 $P> 0.1$

The feeding experiments with *Pinus nigra* litter collected exclusively in October lasted from December till June. It is to be noted that also under natural circumstances, in scots pine forests (occupying larger and larger areas in the Hungarian mountains), the litter of this coniferous species can be the most important food source for the litter arthropod communities. Data in Table 2 clearly show that after a very low consumption level in December/January a relatively quick increase (10x) in the animals' feeding activities was observed, which later reached a steady daily litter consumption intensity of about 5 mg litter/g body weight. The amount of the consumed food material differred significantly in the the first two experimental feeding series (Table 2/a).

Table 2. Needle litter (Pinus nigra) consumption and faecal pellet production by S. stigmatosum adult specimens (SD)

Month of experiment	Consumption mg / g / day		Egestion (SD)	
Dec/Jan	1.4	(2.4)	1.2	(0.4)
Jan/Febr	12.6	(0.8)	6.6	(0.9)
Febr/March	5.3	(1.2)	5.2	(1.8)
May/June	5.8	(2.0)	3.3	(1.4)

Table 2/a. A comparison of needle litter consumptions measured in different months (t-test)

	Dec/Jan	Jan/Febr	Febr/March	May/June
Dec/Jan	-	xxxx	xxxx	**
Jan/Febr		-	xxxx	xxxx
Febr/March			-	0
May/June				-

Significant differences: xxxx P< 0.001
** P< 0.02
0 P> 0.1

It can be supposed, that the low feeding intensity of the animals in the first months of the experiment (in Oct/Nov), was due to "stress" conditions evolved under the unusual artificial experimental conditions. Such observations were published also by GERE (1962). On the other hand, it seems to be also very probable that the outstandingly high feeding activities of the animals during the next months (Dec/Jan) was due to a compensation effect against the previous stress conditions. Further studies would be necessary to clarify the changing animal behaviour (food consumption, digestion and respiration activities, etc.) under radically changed environmental circumstances.

The comparison of the results of the broad-leaved and needle litter consumption experiments, carried out in about the same time (since the leaf litter were given the animals about three weeks after they were collected), revealed a significant difference in the ingested mass of the two different litter sorts (during December and January) (Table 3). During the subsequent months such significant differences were not detected at all. In this case we can also suppose the existence of a "stress" effect caused partly by putting the animals into the pots as an unusual environment, partly by the given food which was unknown for them. Nevertheless, the fed animals were sampled from the litter layer of a broad-leaved forest stand, where scots pine did not occur.

Table 3. A comparison of leaf and needle litter consumptions (t-test)

	Leaf litter			
	October	December	February	April
Needle litter				
Dec/Jan	xxxx			
Jan/Febr		xxxx		
Febr/March			0	
May/June				0

Significant differences: xxxx P< 0.001
0 P>>0.1

The litter cosumption of soil inhabiting saprophagous animals belonging to the most different taxonomic groups showed a very characteristic general decrease in spring during a lot of long-term feeding experiment series carried out in the eighties in our cave laboratory (Enchytraeidae - DÓZSA-FARKAS, 1982; Lumbricidae - ZICSI, 1983; Diplopoda - POBOZSNY, 1986). The same phenomenon was observed during our needle litter feeding experiments, altough in these cases neither the quality of the food nor the environmental paremeters were changed.

Analysing the number and frequency of animal species collected in soil traps placed in beech and hornbeam-beech stands in the Bakony Mountains, ILOSVAY (1982) studied the seasonal frequency of the occurrence of *S. stigmatosum*. Between January and July two peaks were found: one in March and another in May. Comparing the moving activity curve of ILOSVAY and our data on the consumption activities of this millipede species, the feeding activity peaks can be said to precede consequently the appearence of the highest number of individuals in traps with both food types (Fig. 1). Unfortunately, the animals' occurrency data are limited to seven months of the year only in ILOSVAY'S paper. According to our long-term observations, the specimens of this species are active and feeding during the whole year apart from the frozen months. The reproduction of *S. stigmatosum* occurs from April to the beginning of June (SEIFERT, 1932), and closely correlates with the food consumption intensity.

There is a linear correlation between food consumption and faecal pellet production (DUNGER, 1958; POBOZSNY, 1985).

Food preference

During October, the experimental specimens of *S. stigmatosum* consumed practically nothing from the freshly fallen leaves exposed as food for them. This finding can be correlated with the known fact, that freshly fallen leaves are not attacked by many soil dwelling animals before they are not degraded to a certain extent by microbes involving the elimination of harmful or disagreable taste-materials. As this advantageous introductory transformation of the leaf litter is carried out, increasing feeding activities of the animals will be detectable and the litter consumption will be faster and faster. E. g. the relative amount of the already "prefermented" hornbeam litter consumed by *S. stigmatosum* continuously increased from December (Fig. 2). In general, the leaves of beech and oak trees fall mostly during November and December, but sometimes later, depending on the actual weather circumstances and the age of the trees, in October, besides the freshly fallen leaves of hornbeam, the litter layers of these forests still contain more or less degraded old oak and beech leaves, which remained on the soil surface from the previous year. The old, microbially attacked leaves are consumed more rapidly by millipedes than those which are colonized by less microorganisms (Fig. 2). It is a remarkable phenomenon that the consumption of beech leaves very suddenly increases, after a prefermentation period.

Studying the order of preference of *S. stigmatosum* in relation to the fallen leaves of broad-leaved species we established, that in October, when freshly fallen hornbeam leaves remained untouched, the animals fed most intensively on *Q. petraea* leaves, less actively on those of *Q. cerris*, while they consumed the leaves of *F. silvatica* only sporadically. If the mixed leaf litter collected in December for feed-

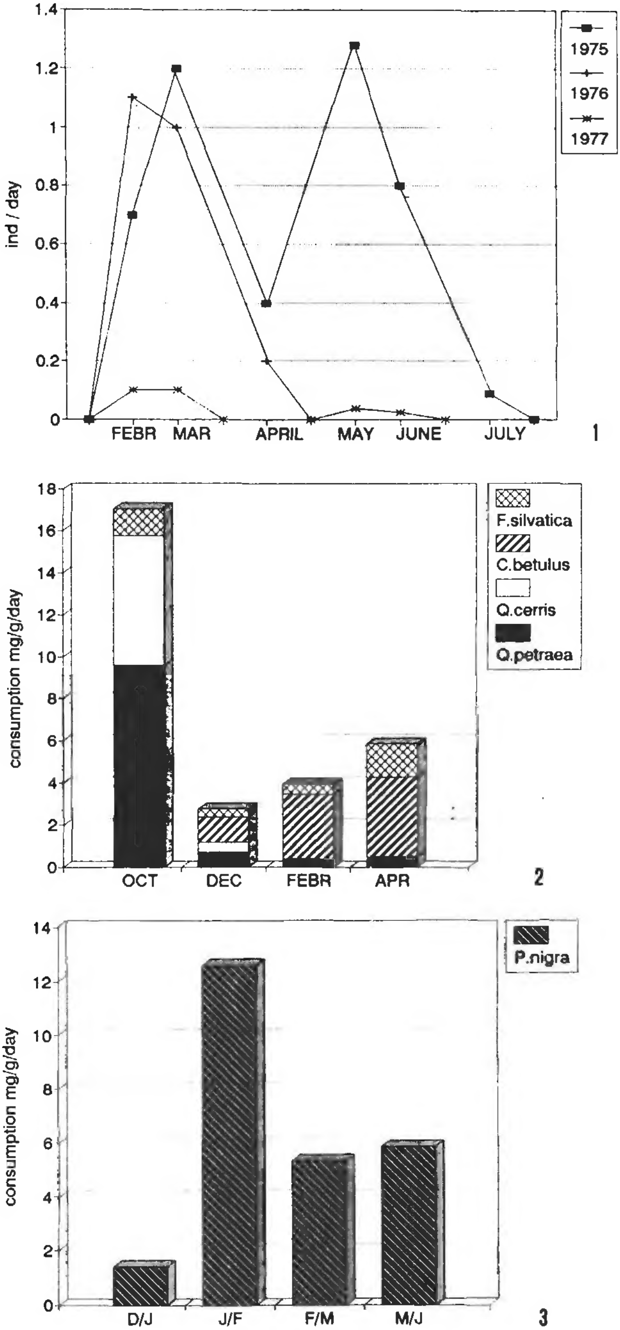

Fig. 1. A comparison of changes in seasonal activities (1: according to ILOSVAY, 1983) and changes in the intensity of litter consumptions (2: from leaf litter; 3: from needle litter) measured during a similar period of the year in our feeding experiments with *S. stigmatosum*

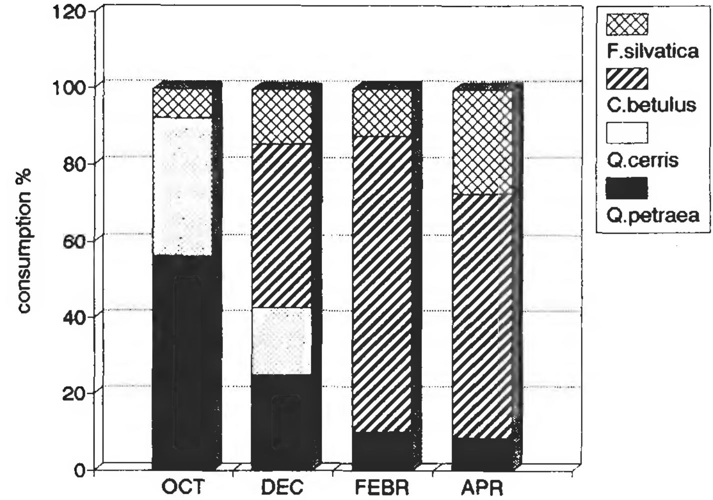

Fig. 2. Distribution of litter consumptions of *S. stigmatosum* adults according to their preference among the exposed leaf litter of four tree species (per cent)

ing, when the different kinds of freshly fallen leaves were already more or less attacked by microorganisms, the preference order was as follows: *Carpinus betulus* > *Q. petraea* > *Q. cerris* > *F. silvatica.* In cases of microbiologically even more colonized and decomposed mixed litter samples collected in February and April the observed order of preference was as follows: *C. betulus* > *F. silvatica* > *Q. petraea.*

It is to be noted, that SEIFERT (1932) fed specimens of *Strongylosoma pallipes* (*S. stigmatosum*) with the leaf litter of mapple, beech, alder and oak. These specimens preferred leaves of mapple but negligated those of oak. This finding was explained by the author with the unfavourably high tannin content and the hardness of the oak leaves.

Table 4. summarizes data of our earlier feeding experiments (POBOZSNY, 1992) carried out with *S. stigmatosum* specimens and different, separately given needle litter sorts (the experiments lasted 60 days). The below given preference order was detected: *Picea abies* > *Pinus nigra* > *P. sylvestris* > *P. strobus*.

Table 4. Consumption and faecal pellet production by S. stigmatosum adult specimens fed on different sorts of needle litter (Pobozsny, 1992)

	Consumption		Egestion	
	mg / g / day	(SD)		
Pinus nigra	6.9	(0.6)	4.0	(0.3)
Picea abies	9.9	(0.7)	8.1	(0.6)
Pinus sylvestris	2.3	(0.3)	2.5	(0.5)
Pinus strobus	2.1	(0.3)	1.5	(0.2)

Survival, body weight, assimilation efficiency of the animals

The studied millipede specimens proved to be able to survive the created experimental stresses and the feeding with needle or broad-leaved litter matter with different mortality rates in the different months of the year (Table 5). Significant differences were found comparing the number of survivors fed on leaf litter in October, December and April (Table 5/a). On the other hand, only less significant differences were found in the mortality rates of the animals fed with *P. nigra* needle litter during December/January and February/March as well as in February/March and May/June (Table 5/b). The numbers of survivors fed separately on leaf or needle litter in experiments carried out at the same time, differred significantly in December and January/February, furthermore also in April and May/June, respectively (Table 5/c).

A consequent decrease in the body mass of the fed spimens was detected during all experimental series (Table 5). This decrease was the highest with animals fed on leaf litter collected in April, and the lowest (only 0.3 per cent) with those fed on needle litter. Remarkable differences were not found in body mass losses regarding those animals, which were fed on leaf litter collected in February and during other months (Table 5/a). However, highly significant differences were found in body mass losses between the members of those two groups of animals which were fed at the same time (late April—May/June), on broad leaves collected in April, on the one hand, and on needle litter collected in October, on the other (Table 5/c).

Table 5. Survival, changes in the body mass and the level of assimilation efficiency of S. stigmatosum adult specimens during the different feeding experiments (SD)

Experiment	Survival %		Changes in the body mass %		Assimilation efficiency A/C %	
On leaf litter						
October	93.0	(9.9)	- 5.8	(11.5)	42.2	(22.3)
December	59.0	(23.6)	-31.6	(22.7)	61.2	(0.1)
February	63.5	(20.7)	-27.7	(21.2)	29.6	(10.0)
April	22.0	(6.0)	-78.3	(6.4)	34.0	(4.9)
On needle litter of Pinus nigra						
Dec/Jan	100.0	(0.0)	-21.3	(12.6)	23.6	(56.6)
Jan/Febr	96.0	(8.0)	- 0.3	(9.0)	47.6	(5.7)
Febr/March	66.0	(21.5)	-28.4	(18.6)	37.0	(32.1)
May/June	94.0	(8.0)	-11.3	(8.9)	43.9	(10.9)

Table 5/a. A comparison of data obtained in a series of leaf litter feeding experiments with adult specimens of S. stigmatosum (t-test)

	October	December	February	April
Survival				
October	-	xxxx	0	xxxx
December		-	0	0
February			-	0
April				-
Body-mass change				
October	-	xxxx	0	xxxx
December		-	0	xxxx
February		-	-	0
April				-
A / C				
October	-	0	0	0
December		-	0	xxx
February			-	0
April				-

Significant differences: xxxx P< 0.001
xxx P< 0.002
0 P> 0.1

Table 5/b. A comparison of data of needle litter (P nigra) feeding experiments made with S. stigmatosum adult specimens (t-test)

	Dec/Jan	Jan/Febr	Febr/March	May/June
Survival				
Dec/Jan	-	0	x	0
Jan/Febr		-	0	0
Febr/March			-	*
May/June				-
Body-mass change				
Dec/Jan	-	**	xxx	xxx
Jan/Febr		-	**	0
Febr/March			-	xx
May/June				-
A / C				
Dec/Jan	-	0	0	0
Jan/Febr		-	0	0
Febr/March			-	0
May/June				-

Significant differences: xxx P< 0.002
xx P< 0.005
x P< 0.01
** P< 0.02
* P< 0.05
0 P> 0.1

Table 5/c. A comparison of data of leaf and needle litter feeding experiments made with S. stigmatosum adult specimens (t-test)

	October	December	February	April
Survival				
Dec/Jan	0			
Jan/Febr		xxx		
Febr/March			0	
May/June				xxxx
Body-mass changes				
Dec/Jan	x			
Jan/Febr		x		
Febr/March			0	
May/June				xxxx
A / C				
Dec/Jan	0			
Jan/Febr		xxxx		
Febr/March			0	
May/June				0

Significant differences: xxxx $P< 0.001$
xxx $P< 0.002$
x $P< 0.01$
0 $P> 0.1$

These results may be explained by the unadequate quality of the given litter food, which made possible only the survival of the animals. There was a possibility of coprophagy for these animals, too (SZLÁVECZ & POBOZSNY, 1995). Nevertheless, the accumulated faecal pellets were removed from the pots only at the time of feedings.

The calculated assimilation efficiency values (Table 5) eventually may also refer to coprophagy (MCBRAYER, 1973; POBOZSNY & al., 1995). Although there are authors (e.g. GERE, 1956), who suppose that diplopods assimilate the consumed food only at a low rate (<10%), we found that the value of assimilation efficiency was considerably higher with *S. stigmatosum* adult specimens, in all of our experiments, it exceeded 20 per cent. In an exceptional case, with leaf litter it was even 61.2 per cent (Table 5). The assimilation efficiency of animals which were fed on needle litter showed no significant differences during the different months (Table 5/b). Similarly, with animals fed on leaf litter we detected difference in the assimilation efficiency only in one single case, between December and April (Table 5/a). Comparing the assimilation efficiencies of animals fed on needle and broad-leaved litter no significant differences, with the exception of one case, were found (Table 5/c).

It seems to be necessary to remark that, because the body mass of the animals was frequently decreasing, the absorbed food materials were used mostly for generating energy and not for biomass production, owing to the measured high assimilation efficiency. The body mass loss may also be due to the increased energy requirement of the animals. The reasons for this process are unknown. It is an observed fact, however, that although under stress the animals can eventually consume more food than usually, they show considerable body weight-loss. Concerning the real level of assimilation efficiency of these animals still further studies are needed.

On the basis of our above presented findings we suppose that, without respect on the amount of the consumed food matter and the time of their feeding activities, adult specimens of *S. stigmatosum* could always assimilate the consumed food with very similar efficiency levels under the given experimental conditions.

Conclusions

S. stigmatosum, a widespread diplopod species in the litter layers of the Hungarian broad-leaved and mixed forest stands, is an important member of the organic matter decomposing soil communities, possessing a considerably broad food spectrum. It has a high survival capacity and may be able to survive the radical changes in tree species compositions of forest stands caused by de- and reafforestations.

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